BEARING MATERIAL

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0001] The invention relates to bearing materials. More particularly, the invention relates to anti-friction materials for journal bearings.

(2) Description of the Related Art

[0002] Journal bearings are used as structural supports for rotating parts. Hydrodynamic bearings utilize a film of liquid lubricant between the journal pin and bushing. In common configurations, the journal pin is formed of a relatively rigid, non-lubricious, material. The bushing, or at least a surface layer thereof, is formed of a more compliant, more lubricious, bearing material. Advantageous properties for such bearing materials involve an appropriate combination of lubricity, high thermal conductivity, and fatigue strength. Lubricity is desirable even in the context of a hydrodynamic bearing to augment the liquid lubricant and address abnormal conditions causing local or total loss of liquid lubricant. Common metallic journal bearing materials include alloys or other combinations of tin, lead, aluminum, silver, and copper. Of particular interest are the journal bearings of planetary gears in fan drive gear systems for turbofan engines. Exemplary bearing material in that application utilizes copper as a base constituent and lead as a solid lubricant. Exemplary lead concentrations are 21-30% by weight. Exemplary manufacturing techniques involve codeposition of the copper and lead to create a copper matrix with embedded lead particles. Other materials may be used. For example, U.S. patent 6,588,934, the disclosure of which is incorporated by reference herein as if set forth at length, discloses a copper-silver combination.

[0003] Nevertheless, there remains room for improvement in the art.

SUMMARY OF THE INVENTION

[0004] One aspect of the invention involves a journal bearing system. The system includes a bushing and a journal pin within the bushing. At least one of the bushing and journal pin has an engagement surface with an engagement length comprising a substrate material and a solid lubricant. A concentration of the solid lubricant varies along the engagement length.

[0005] In various implementations, the concentration may be higher near ends of the engagement length than in an intermediate portion. The concentration may vary by at least

50% of a maximum value along said engagement length. The base material may comprise a coating applied to a substrate. The apparatus of the substrate may comprise a copper-based material and the solid lubricant may comprise a metal. The solid lubricant metal may comprise lead. The concentration may be greater than 30% at first and second locations near first and second ends of the engagement length and 10-30% in an third location, between the first and second locations. The concentration may be greater than 35% at first and second locations within first and second terminal 20% of the engagement length and 10-30% over a majority of a central 50% of the length. The system may support a gear in a turbofan transmission.

[0006] Another aspect of the invention involves a hydrodynamic bearing apparatus comprising a bushing, a journal pin, and means for providing extended operation after a lubricant loss. In various implementations, the means may comprise a longitudinally varying lead concentration within a copper matrix.

[0007] Another aspect of the invention involves a method for preparing a lining for a hydrodynamic bearing. A solid lubricant is applied along the lining, the solid lubricant being applied with concentration that varies along a length of the lining.

[0008] In various implementations, the application of the solid lubricant may comprise sputtering. The application of the solid lubricant may be simultaneous with the application of a base material.

[0009] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The figure is a semi-schematic longitudinal sectional view of a bearing system according to principles of the invention.

[0011] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0012] The figure shows a bearing system 20 comprising a journal 22 and a bushing 24. The exemplary journal has shaft portions 26A and 26B at first and second ends mounted to associated carrier plates 28A and 28B. The journal has a central portion 30 having a cylindrical bearing surface 32. A lubrication passageway 34 extends to the surface 32 from a central passageway (not shown) to introduce liquid lubricant (e.g., oil) to a space between the bearing surface 32 and a mating bearing surface 35 of the bushing. The exemplary bushing includes a substrate 36 and a coating 38 applied to an inner (interior) cylindrical surface of the substrate. The interior cylindrical surface of the coating 38 provides the bushing bearing surface 35. In the exemplary embodiment, the coating extends along a length L between first and second ends 40A and 40B and has a thickness T. In an exemplary application, the substrate 24 may be a metallic (e.g., steel) planetary gear in a fan drive transmission of a turbofan engine. In such an application, the journal 22 may also be formed of steel. An exemplary coating 38 comprises a base material (e.g., copper) and a solid lubricant (e.g., lead). The combined base and solid lubricant materials may be gradually built up on the substrate inner surface. Exemplary codeposition techniques include sputtering (e.g., U.S. patent 4,904,362), electron jet vapor deposition (e.g., U,S. patent 5,571,332), chemical vapor plating (U.S. patent 4,788,082), plasma spraying, and electroplating.

[0013] With an exemplary engagement region between the two bearing surfaces sharing the length L, according to the present invention the composition of the coating 38 varies longitudinally along such engagement region. In the exemplary embodiment, the coating composition may be circumferentially uniform at any given longitudinal position. In the exemplary embodiment, the coating composition may be radially uniform at an given longitudinal position.

[0014] In the exemplary embodiment, the composition non-uniformity provides relatively high concentrations of solid lubricant near the ends 40A and 40B and relatively low concentrations in a central region. With uniform coating compositions, a loss of the hydrodynamic lubrication typically results in bearing failure (e.g., melting and/or seizure). Failures are typically observed near the needs of the bearing. The higher than normal solid lubricant concentrations may avoid or delay such failure. The remaining lesser concentration region serves to provide sufficient bearing static strength and wear resistance during normal operation. For example, a uniform high concentration of solid lubricant might leave the coating with too little strength to resist static deformation and achieve a desired normal operating life.

[0015] The drawing shows high solid lubricant concentrations regions 50A and 50B and a central low concentration region 52. In the exemplary implementation, the dividing lines between the high and low concentration regions may occur approximately 25% of the length L inboard of the end portions. Clearly, however, in many implementations abrupt changes in concentration may be impractical. The changes may be as abrupt as any given manufacturing technology can provide or may be yet more gradual. In an exemplary implementation, the dominant concentration in the central region 52 is a fairly standard 28% lead (by weight unless otherwise identified). This may represent the minimum concentration along the length. The dominant concentration in the end regions may be in the range of 35-45% lead. The peak of this value may represent the maximum concentration along the length. An exemplary broader concentration for the central region is 20-30%. An exemplary broader concentration for the end regions is 30-50%. The end region lengths may be 25%, 20%, 15%, and 10%. Concentrations in any given region may be measured in terms of concentration at any point in the region, mean concentration, median concentration, or other characteristic concentration. Exemplary coating thicknesses T are 0.0005-0.0045 inch, more narrowly 0.0010-0.0030 inch. Although illustrated with respect to a symmetric distribution, a distributed loading (especially loading in lubrication failure conditions) may suggest asymmetric distributions. For example, the end regions may be of different lengths and the peak or other characteristic concentrations in those regions may differ. Even within the basic copper-lead system described, other components may be included for a variety of purposes as are known in the art or may yet be developed.

[0016] One or more embodiments of the present invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. For example, the principles of the invention may be applied to existing or other bearing configurations and to existing or other manufacturing techniques. The particular uses, configurations, and techniques may influence any particular implantation. Accordingly, other embodiments are within the scope of the following claims.